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AGE, LENGTH, SEX, AND ABUNDANCE OF ARCTIC GRAYLING IN MINERAL LAKE OUTLET, 1969 - 1988[1]

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ABSTRACT

Arctic grayling *Thymallus arcticus* were captured by beach seine in Mineral Lake Outlet during spawning from 10 through 25 May 1988. Temporal changes in age, size, and sex compositions were noted during sampling, although pooling of data from selected sampling events provided representative samples from the adult population. The length at maturity and size composition of the Mineral Lake Outlet spawning stock was significantly less than that found in two spawning stocks located 282 kilometers downstream. The abundance of adult male Arctic grayling in the head pool of one spawning area was 171 fish (standard error was 12 fish).

KEY WORDS: Arctic grayling, *Thymallus arcticus*, Mineral Lake Outlet, age composition, size composition, sex composition, maturity, relative stock density, spawning stock, hooking damage, population abundance.

INTRODUCTION

Mineral Lake Outlet (referred to as the Outlet in this report) flows approximately 3.2 km from Mineral Lake downstream to the confluence with the Little Tok River approximately 64 km south of Tok on the Glenn Highway (Tok Cut-Off). The lower 0.8 km of the Outlet borders the highway. The Outlet is a spawning area for Arctic grayling *Thymallus arcticus* that overwinter downstream in the Little Tok, Tok, and Tanana Rivers and occupy other parts of the Little Tok River drainage both up and downstream during the summer (Tack 1974). It is one of the few spots in Interior Alaska that offers highway access to a discrete and concentrated spawning population of Arctic grayling. This population has offered a small but popular spring fishery for the residents of Tok and Mentasta since at least the early 1960's (Tack 1974; Pearse pers. comm.). Between 1969 and 1973, studies were conducted at the Outlet that primarily described spawning behavior and migrational timing to determine a suitable sight for an egg-take (Roguski and Tack 1970; Tack 1971, 1972, 1973). Population data were limited to one year of data on age composition, age at maturity, and growth. There also exists a small data base on hook and line captures in files at the Delta Junction field office that were never published. Harvest and effort data is limited to one entry in the field office files that summarizes a four day census effort from 19 to 27 May, 1973 with 45 anglers interviewed. The anglers harvested 170 Arctic grayling in 141 hours for a harvest rate of 1.21 Arctic grayling per hour.

In 1987, local concern was voiced over a perceived decline in numbers and size composition of the recreational harvest. This concern, coupled with a growing local population due to the recent installation of a U.S. Coast Guard LORAN Site and the planned construction of an Army Radar Site, led to the inclusion of the Outlet fishery in the set of special regulations for Arctic grayling in the Tanana River drainage in 1988. These regulations included catch and release until the first Saturday in June, a 305 mm total length limit, and a no bait restriction.

This study was undertaken to initiate a data base from which to assess the stock status of the Outlet fishery. This report summarizes all population data collected from 1970 to 1988. The research objective for 1988 was to estimate the age composition of the population of Arctic grayling $\geq$ 150 mm fork length (FL) during May in the Outlet.

METHODS

Sampling in 1988 began on 10 May and ended on 25 May. A total of 14 sampling events occurred over a seven day period. Five of these events were combined into two events to maximize sample size of the events (see Appendix Table 1). Events occurred during the in-migration of Arctic grayling and extended through the spawning period to the out-migration of adults. Tack (1971, 1972, 1973) reported that initiation of spawning at the Outlet (1969 through 1972) ranged from 18 May to 2 June. In 1988, the first spawning activity was noted on 17 May. The intent of the sampling was to acquire a representative age composition of the Arctic grayling population during the time of spawning.

Fyke traps blocking the mouth and headwater were planned as the primary capture gear by blocking the mouth and head waters of the Outlet. However, ice and water conditions prevented their use. A 6.4 mm mesh bag seine (23 m x 1.8 m) was used as an alternate gear to collect the samples, but gear efficiency was sometimes reduced by deep pools and/or debris.

Sampling with the seine was conducted at six sites along the Outlet (Figure 1). Sites 1 through 5 were in spawning areas (shallow, gravel bottomed runs), whereas site 6 was at the head of a deep, mud bottom pool that extended 135 m to the confluence with the Little Tok River. Since the majority of sampling occurred during spawning (17 to 20 May), repetitive seining was restricted to sites 1 and 6 to minimize possible adverse effects to deposited eggs. Site 1 was the largest spawning area with a length of 80 m. Sampling at site 1 was restricted to one location encompassing the upper 16 m. Site 6 was also sampled in a single location using a boat to deploy the seine.

All captured Arctic grayling were anesthetized with MS-222 prior to sampling. After data collection, the fish were allowed to recover prior to release. Fish captured during repetitive seine hauls were placed in a holding pen or tub prior to data collection. All Arctic grayling greater than 199 mm were tagged with Floy FD-67 anchor tags and given an adipose fin clip.

Estimation of Abundance

Abundance of adult Arctic grayling was estimated during a 24 hour period at site 1 with the modified Peterson formula of Bailey (1951, 1952):

$$(1) \qquad \hat{N} = \frac{M\,(C + 1)}{(R + 1)} - 1$$

where: M = the number of Arctic grayling marked and released alive during the first sample;
C = the number of Arctic grayling examined for marks during the second sample;
R = the number of Arctic grayling recaptured during the second sample; and,
$\hat{N}$ = estimated abundance of Arctic grayling during the first sample.

Variance of the abundance estimate was estimated by (Bailey 1951, 1952):

$$(2) \qquad \hat{V}[N] = \frac{\hat{N}\,M\,(C - R)}{[(R + 1)(R + 2)]}.$$

The necessary assumptions for an accurate estimate are:

1) the Arctic grayling population in the study area must be closed;

2) no tags can be lost between samples;

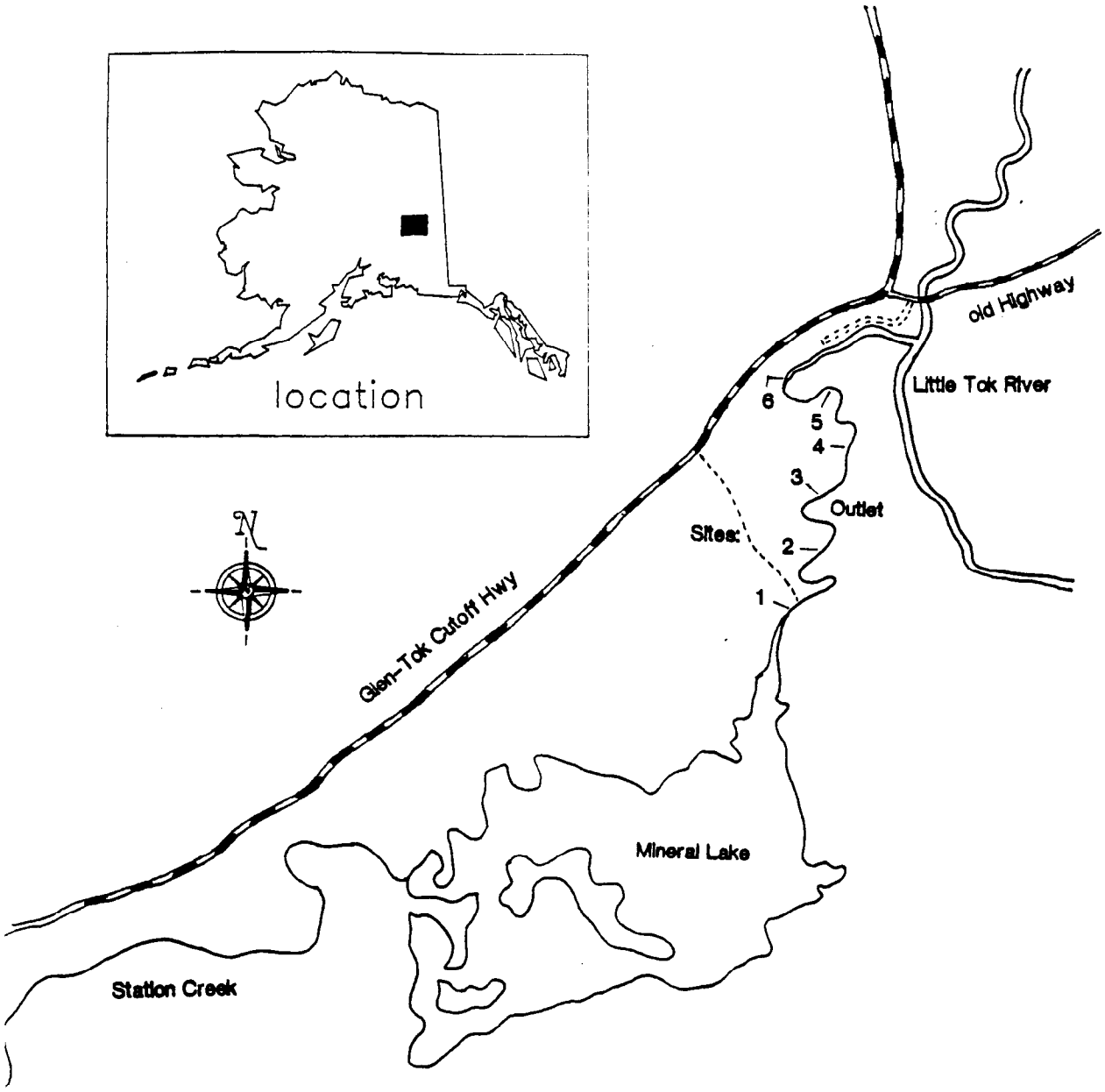

Figure 1. Map of Mineral Lake Outlet study area.

3) all Arctic grayling have the same probability of capture during the first sample or during the last sample or marked grayling must completely mix with unmarked grayling between samples;

4) marking must not influence behavior between samples; and,

5) mortality is the same for both marked and unmarked fish between samples.

The short interval between samples and the fact that the targeted population were in the act of spawning satisfied the first assumption. Fin-clipping in addition to tagging allowed measurement of bias due to the second assumption. For the third assumption, two statistical tests were performed. Two-tailed Kolmogorov-Smirnov tests (Conover 1980) were applied to: 1) lengths of recaptured and not recaptured fish to detect differences in catchability; 2) lengths of marked and not marked fish captured during the recapture event to detect recruitment/emigration; and, 3) lengths of fish caught during the marking event and lengths of fish in the recapture event to detect gear selectivity. Chi-square tests were used to detect differences in catchability between the sexes. If these tests showed significant differences, the data were stratified by length and/or sex.

Sex and Maturity

Since sampling was conducted during spawning of Arctic grayling, sex and maturity were readily determined by either sexual dimorphism or the presence of milt or eggs. Dimorphism is evident in differences in length of the dorsal fin (the male dorsal fin usually extends to the adipose fin whereas the female dorsal fin is noticeably shorter) and the swelling of the anal vent and abdomen fullness (gravid) or flaccidity (spawned out) in females. Some error was associated with the use of these morphological characteristics as the sole determinant of sex. For example, at the time of sampling, small males may have been classed as juveniles since their dorsal fin may not have reached the adipose and, if recently spawned, they would not have given milt. Sex ratios were presented as the ratio of the number of males to females when initially captured. The percent of mature grayling by sex was recorded by length class and by age group. Since more than one length or age category had mature fish, probit analysis was used to estimate the lenth or age at which 50% of the fish were mature (LM_{50} or AM_{50}; Finney 1971).

Estimation of Age and Size Composition

All captured Arctic grayling were measured to the nearest 1 mm FL. For aging, a minimum of two scales from all initial captures greater than 149 mm FL were removed from an area 4 to 6 scale rows above the lateral line just posterior to the insertion of the dorsal fin. Scales were processed by cleaning in a hot solution of common dish detergent. They were then inspected for regeneration, and then the two best scales from each fish were mounted on gummed cards. The cards were used to make impressions of the scales on 20 mil acetate film using a Carver press at 7,000 kg/cm^2 heated to 97°C. Ages were determined by replicate readings with the aid of a microfiche reader.

An unbiased estimate of the proportion of Arctic grayling in each age class was calculated by:

$$(3) \qquad \hat{p}_i = \frac{y_i}{n}$$

where:

y_i = the number of Arctic grayling of age i in the sample; and,
n = the number of Arctic grayling in the sample.

The unbiased variance of this proportion is:

$$(4) \qquad V[\hat{p}_i] = \frac{\hat{p}_i\,(1 - \hat{p}_i)}{n - 1}$$

Age class composition of the Arctic grayling stock greater than 149 mm FL was estimated by summing the weighted age compositions from selected sampling events to account for changes in size composition between events. The events were chosen on the basis of a series of Kolmogorov-Smirnov tests between various combinations of events and an intuitive estimate of when the population was in migratory stasis. Age class proportions and their variances for selected samples were first calculated with equations 3 and 4. These statistics were then weighted by sample size on the assumption of equal probability of capture:

$$(5) \qquad \hat{p}_i = \sum_{h=1} W_h \hat{p}_{hi}$$

where:

$$(6) \qquad W_h = \frac{n_h}{\sum_{h=1} n_h}; \text{ and,}$$

$\hat{p}_{hi}$ = the proportion of grayling of age i in sample h; and,
n_h = number of grayling in sample h.

The unbiased variance of the weighted proportion is:

$$(7) \qquad V[\hat{p}_i] = \sum_{h=1} [W_h]^2 \, V[\hat{p}_{hi}]$$

The age composition of male and female Arctic grayling was calculated by pooling all age samples. The nature of the movements that affected accurate estimation of the composition of the whole population, i.e. the emigration of juvenile fish, was considered not germane to the age estimation of adults.

Tack (1972) reported water temperature of 1°C initiating in-migration of adults to spawning areas (Mineral Lake Outlet) and 4°C initiating spawning. Ridder (1983) reported a temperature of 10°C preceded the migration of post-spawning Arctic grayling out of Caribou Creek. Sampling in 1988 commenced at 4°C and ended at 11°C, effectively bracketing the empirical temperature requirements for Arctic grayling during spawning. Length at age was calculated as the arithmetic mean fork length of all captured fish in each age class from all sampling events.

Size composition of initial captures was described with the incremental Relative Stock Density (RSD) indices of Gablehouse (1984). The RSD categories for Arctic Grayling are: Stock (150 to 269 mm FL); Quality (270 to 339 mm FL); Preferred (340 to 449 mm FL); Memorable (450 to 559 mm FL); and Trophy (greater than 560 mm fl). RSD indices were estimated with equations 3 through 7, substituting the RSD categories for age classes.

RESULTS

Age and Size Composition

Size compositions at sites 1 and 6 changed as sampling progressed, indicating continual emigration of adult Arctic grayling during the entire sampling period (Figures 2 and 3). At site 1, the ratio of adults to juveniles decreased significantly from event 1 to 5 (χ^2 = 102.53, df = 4, $P < 0.05$; Appendix Table 1). The significant decrease in this ratio was not altered when event 5 (the 25 May sample, in which no adults were caught) was deleted (χ^2 = 30.04, df = 3, $P < 0.05$). This ratio also changed significantly at site 6 (χ^2 = 14.92, df = 2, $P < 0.05$). A series of 19 Kolmogorov-Smirnov tests on various combinations of samples showed significance differences in 15 of the tests (Appendix Table 2).

These changes in compositions indicated that estimation of age composition of the stock could not have been accomplished by pooling of all sample events. The estimate should have included samples from throughout the Outlet, therefore, some pooling was necessary. Kolmogorov-Smirnov tests indicated no difference in the samples from site 1 and sites 2 through 5 collected on 17 and 18 May. Therefore, these data were pooled and the age composition estimated (Table 1). In addition, the age composition during 18 May at site 6 was estimated (Table 1).

The weighted combination of the above two age composition estimates showed age 3 and 4 Arctic grayling dominated the stock in 1988, with each classes comprising about 26% of the stock (Table 2). Forty-four percent of the stock was age 5 or greater with age 6 and 7 Arctic grayling nearly equally represented.

The pooled age composition estimate from all sampling events was not significantly different from the weighted estimate (χ^2 = 3.81, df = 7, $P > 0.05$). Age 3 Arctic grayling dominated this estimate at 30% of the sample, with Age 4 Arctic grayling comprising 24% (Table 2). Age 5 and older grayling comprised 41% of the sample.

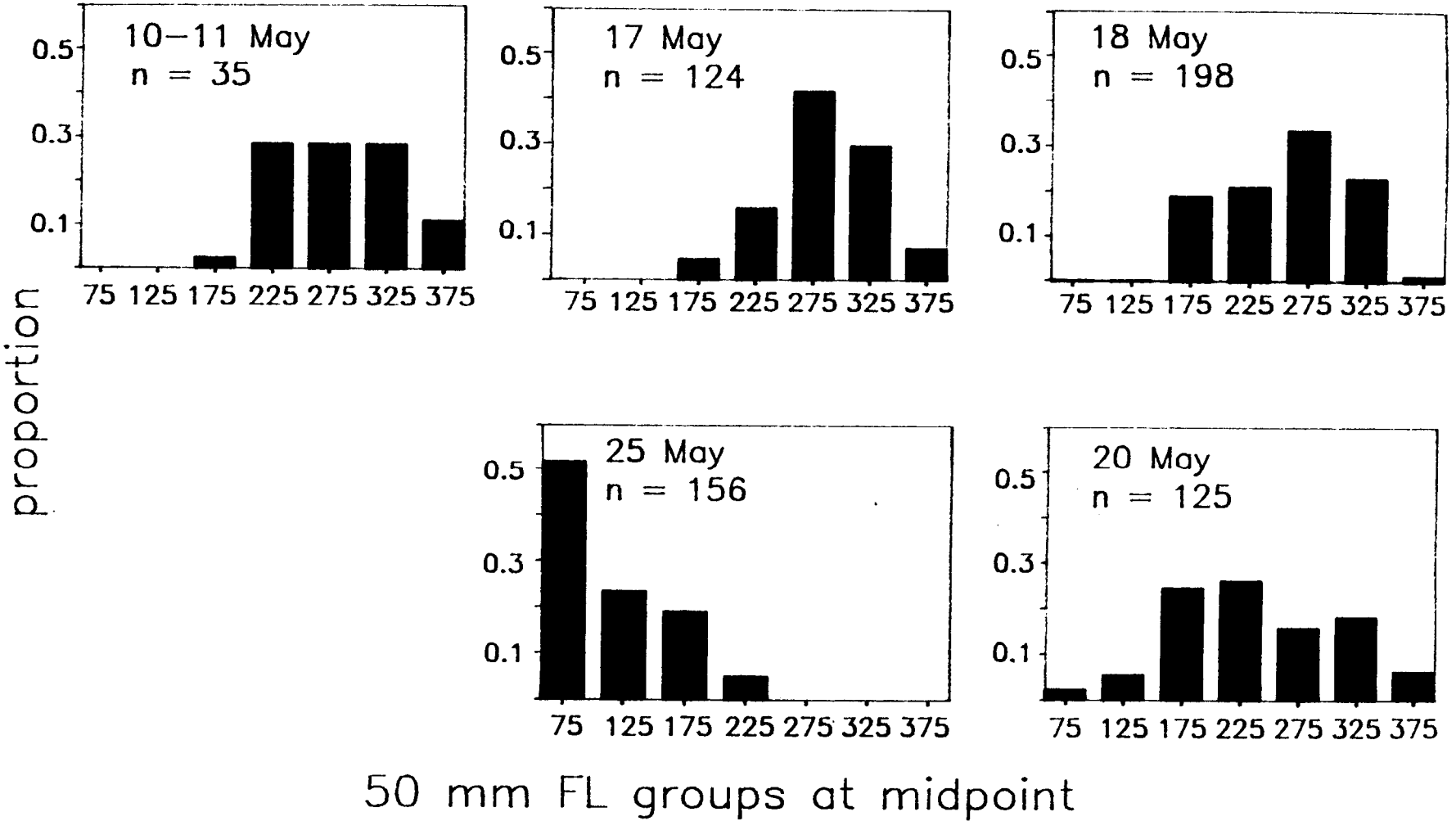

Figure 2. Proportion of 50 mm FL groups of Arctic grayling captured by day at site 1, Mineral Lake Outlet, 10 to 25 May 1988.

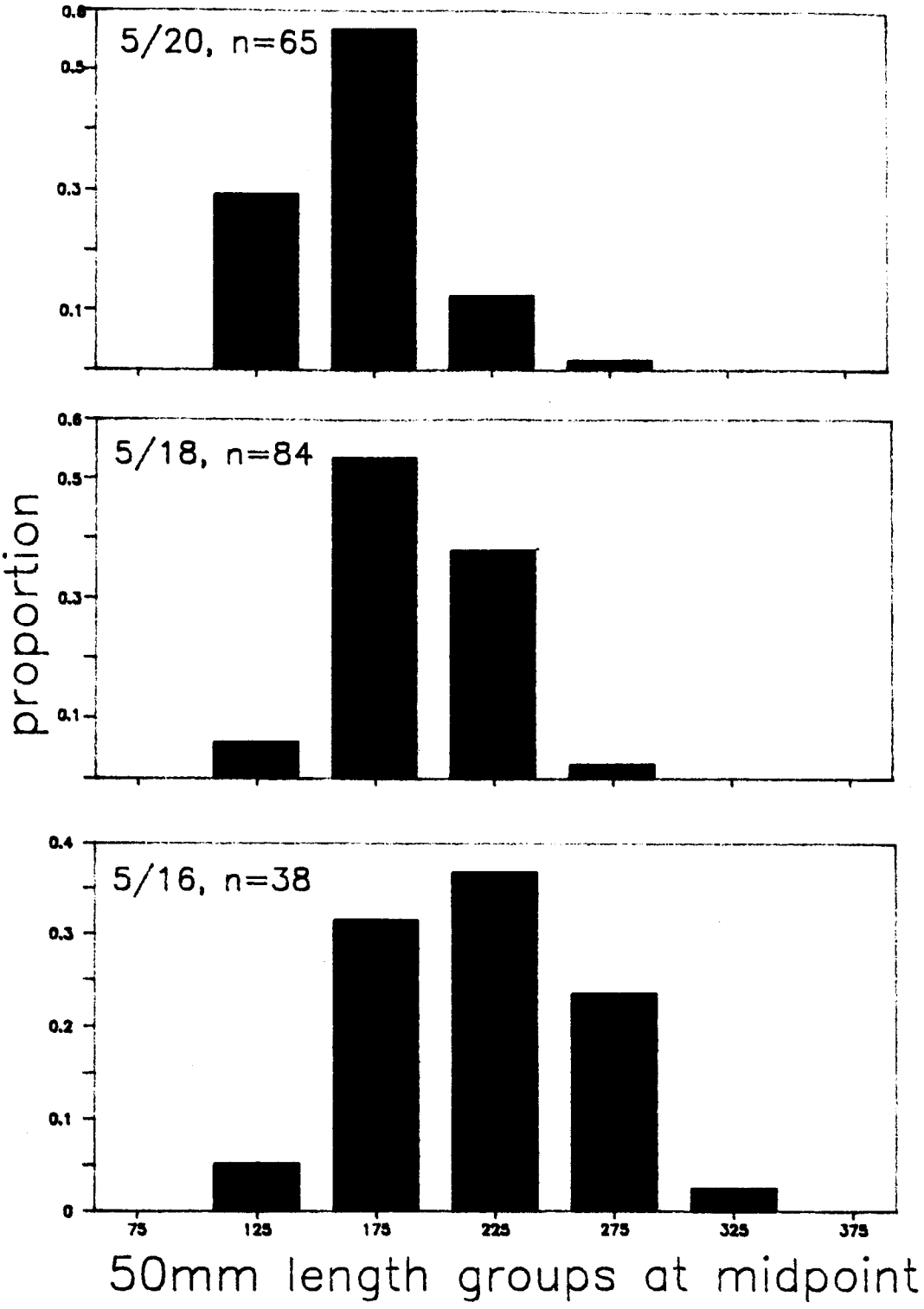

Figure 3. Proportion of 50 mm FL groups of Arctic grayling captured by day at site 6, Mineral Lake Outlet, 16 to 20 May 1988.

Table 1. Estimates of the proportional contribution of each age class for Arctic grayling (≥ 150 mm FL) sampled in Mineral Lake Outlet at sites 1 through 5 and site 6, 17 and 18 May 1988.

	Sites 1 - 5:			Site 6:		
Age Class	n[1]	p[2]	SE[3]	n	p	SE
2	9	0.042	0.014	2	0.034	0.024
3	44	0.204	0.027	26	0.448	0.065
4	47	0.218	0.028	25	0.431	0.065
5	48	0.222	0.028	3	0.052	0.029
6	27	0.125	0.023	1	0.017	0.017
7	22	0.102	0.021	1	0.017	0.017
8	12	0.056	0.016	0	---	---
9	5	0.023	0.010	0	---	---
10	2	0.009	0.007	0	---	---
Total	216	1.000		58	1.000	

[1] n = sample size.
[2] p = proportion.
[3] SE = standard error of the proportion.

Table 2. Estimates of the sampled and weighted[1] proportional contributions of each age class for Arctic grayling (≥ 150 mm FL) sampled in Mineral Lake Outlet, 10 to 25 May 1988.

	Sampled:			Weighted:		
Age Class	n[2]	p[3]	SE[4]	n	p	SE
2	31	0.053	0.009	11	0.040	0.012
3	175	0.299	0.019	70	0.255	0.026
4	139	0.238	0.018	72	0.262	0.026
5	96	0.164	0.015	51	0.186	0.023
6	60	0.103	0.013	28	0.102	0.018
7	39	0.067	0.010	23	0.084	0.017
8	29	0.050	0.009	12	0.044	0.012
9	10	0.017	0.005	5	0.018	0.008
10	4	0.007	0.003	2	0.007	0.005
11	1	0.002	0.002	0	---	---
12	1	0.002	0.002	0	---	---
Total	585	1.000		274	1.000	

[1] Estimates in Table 1 pooled and weighted by sample size.
[2] n = sample size.
[3] p = proportion.
[4] SE = standard error of the proportion.

In the age composition of adult Arctic grayling pooled from all sample events, age 5 fish dominated in the male sample (35%), while age 5 and 6 fish dominated in the female sample at (27% each; Table 3). While the age of males ranged from 3 to 12 and the age of females from 4 to 10, age compositions were not significantly different by sex ($\chi^2 = 5.80$, df = 5, $P > 0.05$).

Stock size Arctic grayling (150 - 269 mm FL) comprised 59% of the sample at sites 1 through 5, 95% of the sample at site 6, and 65% of their combined weighted sample (Table 4). No grayling in the preferred category were captured at site 6. Seven percent of the weighted sample was in the preferred category.

Adult males and females differed significantly in their size composition (Kolmogorov-Smirnov test: p = 0.0011, D = 0.2253; Figure 4). Twenty-nine percent of adult males and 48% of adult females were stock size (Table 4). Sixteen percent of adult males and six percent of adult females were in the preferred category.

The mean length of 742 Arctic grayling captured at Mineral Lake Outlet was 214 mm FL while the mean length of all adult Arctic grayling was 288 mm FL (Table 5). Adult males were generally larger at age than adult females, although confidence intervals did overlap (Table 6). The mean length of the male sample (294 mm FL) was significantly larger than that of females (277 mm FL; $P < 0.05$).

Population Abundance

Eighty-nine of 441 tagged Arctic grayling were recaptured during sampling in 1988, indicating that a mark-recapture experiment to estimate abundance in the Outlet was possible. An analysis of 9 subsets of these data representing various time, location, and length strata showed significant biases in catchability, selectivity, and, especially, recruitment. This precluded a realistic estimate in all but one subset. The one subset chosen was for adult males in site 1 over the 24 hour period of 17 to 18 May. Kolmogorov-Smirnov two-tailed tests showed no significant biases in capture probabilities (p = 0.5601, D = 0.1741), recruitment/emigration (p = 0.1268, D = 0.2316), or gear selectivity (p = 0.9437, D = 0.0766). The estimated abundance of male Arctic grayling at site 1 on 17 May was 171 fish (SE = 12 males, CV = 7.1%) based on 74 marks, a catch of 97, and 42 recaptures. An estimate of the female population in this sample period was not attempted because only 2 females were recaptured out of 34 marked from a catch of 34.

Sex and Maturity

The length at which 50% of the grayling stock reached maturity (LM_{50}) was estimated from probit analysis of 10 mm FL groups (Table 7) was 237 mm FL (95% confidence interval of 203 to 260 mm). The LM_{90} was 262 mm (95% CI of 244 to 393 mm).

The age at which 50% of the stock reached maturity (AM_{50}) in 1988 was 4.3 years and the AM_{90} was 5.3 years (Table 8). No confidence intervals could be

Table 3. Estimated proportional contribution of each age class for male and female Arctic grayling sampled in Mineral Lake Outlet, 10 to 20 May 1988.

	Male			Female		
Age Class	n[1]	p[2]	SE[3]	n	p	SE
3	1	0.006	0.006	---	---	---
4	21	0.121	0.025	18	0.189	0.040
5	60	0.347	0.036	26	0.274	0.046
6	33	0.191	0.030	26	0.274	0.046
7	27	0.156	0.028	12	0.126	0.034
8	19	0.110	0.024	9	0.095	0.030
9	7	0.040	0.015	3	0.032	0.018
10	3	0.017	0.010	1	0.011	0.010
11	1	0.006	0.006	---	---	---
12	1	0.006	0.006	---	---	---
Total	173	1.000		95	1.000	

[1] n = sample size.
[2] p = proportion.
[3] SE = standard error of the proportion.

Table 4. Summary of Relative Stock Density (RSD) indices for Arctic grayling (≥ 150 mm FL) in six sub-samples (by site and maturity[1]) collected from Mineral Lake Outlet, 10 to 25 May 1988.

	RSD Category[2]				
	Stock	Quality	Preferred	Memorable	Trophy
Site 1 - 5					
Number sampled	142	94	22	0	0
RSD	0.550	0.364	0.085	---	---
Standard Error	0.031	0.030	0.017	---	---
Site 6					
Number sampled	77	2	0	0	0
RSD	0.975	0.025	---	---	---
Standard Error	0.018	0.018	---	---	---
Site Total					
Number sampled	445	169	43	0	0
RSD	0.677	0.257	0.065	---	---
Standard Error	0.018	0.017	0.010	---	---
Weighted RSD[3]	0.648	0.285	0.066	---	---
Weighted SE[4]	0.023	0.023	0.011	---	---
Male Adult					
Number sampled	60	115	33	0	0
RSD	0.288	0.553	0.159	---	---
Standard Error	0.031	0.034	0.025	---	---
Female Adult					
Number sampled	52	50	7	0	0
RSD	0.477	0.459	0.064	---	---
Standard Error	0.048	0.048	0.023	---	---
Adult Total					
Number sampled	112	165	40	0	0
RSD	0.353	0.521	0.126	---	---
Standard Error	0.026	0.028	0.018	---	---

[1] Maturity and sex determined by sexual dimorphism or sex products.
[2] Minimum lengths (FL) for RSD categories are (Gabelhouse 1984):
Stock - 150 mm
Quality - 270 mm
Preferred - 340 mm
Memorable - 450 mm
Trophy - 560 mm
[3] RSD indices weighted for composition bias.
[4] Standard error of weighted RSD.

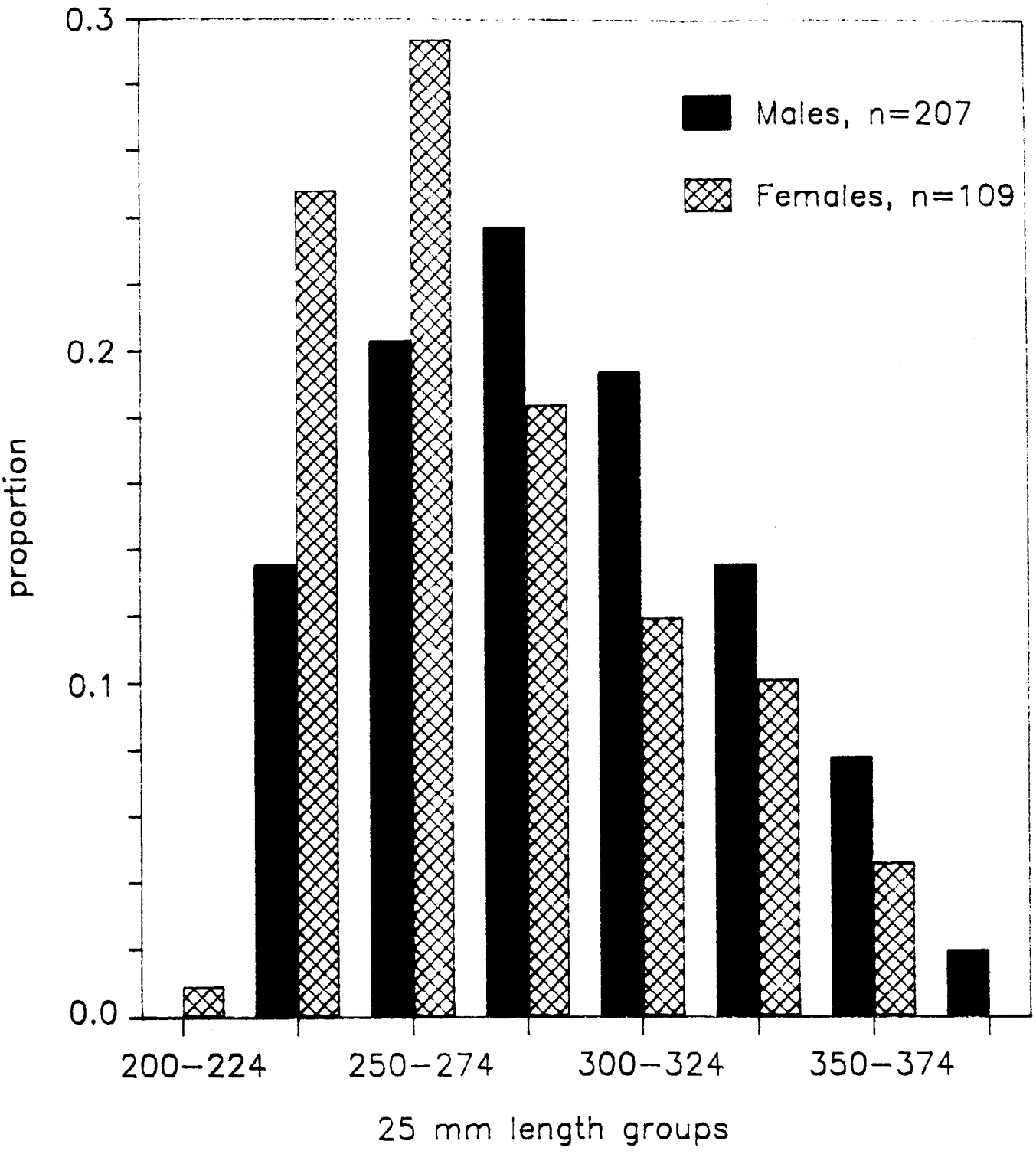

Figure 4. Proportion of adult male and female Arctic grayling in 25 mm FL groups, Mineral Lake Outlet, 10 to 20 May 1988.

Table 5. Estimated mean fork length at age for all Arctic grayling and adult Arctic grayling sampled from Mineral Lake Outlet, 10 to 25 May 1988.

	Total				Adult			
Age Class	n[1]	mean	SD[2]	SE	n	mean	SD	SE
1	102	89	10	1	0	---	---	---
2	79	147	21	2	0	---	---	---
3	182	181	19	1	1	227	---	---
4	139	223	23	2	39	248	17	3
5	96	265	22	2	86	267	20	3
6	60	284	24	3	59	285	24	3
7	39	311	28	4	39	311	28	4
8	29	330	20	4	28	329	20	4
9	10	360	22	7	10	360	22	7
10	4	353	16	8	4	353	16	8
11	1	384	---	---	1	384	---	---
12	1	378	---	---	1	378	---	---
Total	742	214	81	3	268	288	39	1

[1] n = sample size.
[2] SD = sample standard deviation.

Table 6. Mean fork length (mm) at age for male and female Arctic grayling captured by seine in Mineral Lake Outlet, 10 to 20 May 1988.

	Male				Female			
Age Class	n[1]	Mean	SD[2]	SE[3]	n	Mean	SD	SE
3	1	227	---	---	---	---	---	---
4	21	251	18	4	18	244	14	3
5	60	271	20	3	26	257	17	3
6	33	294	22	4	26	273	21	4
7	27	316	26	5	12	300	29	8
8	19	328	21	5	9	330	17	6
9	7	367	19	7	3	344	26	15
10	3	360	7	4	1	331	---	---
11	1	384	---	---	---	---	---	---
12	1	378	---	---	---	---	---	---
Total	173	294	39	1	95	277	36	1

[1] n = sample size.
[2] SD = sample standard deviation.
[3] SE = standard error.

Table 7. Proportion of mature[1] Arctic grayling in 10 mm FL groups sampled in Mineral Lake Outlet, 10 to 20 May 1988.

10 mm Group	N[2]	Mature		
		n[3]	p[4]	SE[5]
<209	402	0	---	---
210 - 219	39	1	0.026	0.025
220 - 229	31	6	0.194	0.071
230 - 239	41	22	0.537	0.078
240 - 249	32	27	0.844	0.064
250 - 259	31	29	0.935	0.044
260 - 269	29	27	0.931	0.047
270 - 279	37	36	0.973	0.027
280 - 289	37	36	0.973	0.027
290 - 299	16	15	0.938	0.061
300 - 309	25	25	1.000	---
310 - 319	18	17	0.944	0.054
>320	76	76	1.000	---
Total	814	317	0.389	0.017

[1] Maturity determined by sexual dimorphism or sexual products.
[2] N = total catch in group.
[3] n = number mature in each group.
[4] p = proportion mature in each group.
[5] SE = sample standard error for the proportion.

Table 8. Proportion of mature[1] Arctic grayling in age classes sampled in Mineral Lake Outlet, 10 to 20 May 1988 and May 1970.

	1988				1970[2]			
		Mature				Mature		
Age Class	N[3]	n[4]	p[5]	SE[6]	N	n	p	SE
2	181	0	---	---	2	0	---	---
3	182	1	0.005	0.005	11	0	---	---
4	139	39	0.281	0.038	32	3	0.094	0.052
5	96	86	0.896	0.031	11	7	0.636	0.145
6	60	59	0.983	0.017	5	5	1.000	---
7	39	39	1.000	---	6	6	1.000	---
8	29	28	0.966	0.034	1	1	1.000	---
≥9	16	16	1.000	---	1	1	1.000	---
Total	742	268	0.361	0.018	69	23	0.333	0.057

[1] Maturity determined by sexual dimorphism or sexual products.
[2] Data from Tack, 1971.
[3] N = total catch in age class.
[4] n = number mature in age class.
[5] p = proportion mature in age class.
[6] SE = sample standard error for the proportion.

calculated by probit analysis. These estimates compare with an AM_{50} of 4.7 years (95% CI of 4.5 to 5.2 years) estimated from data collected in 1970 (Tack 1971).

The estimated sex ratio (males to female) from all initial adult captures was 1.9:1, but was significantly different among the nine sample events ($\chi^2 = 30.51$, df = 5, $P < 0.05$). The ratios found at site 6 and at site 1 during events 4 and 5 skewed the ratio in favor of females (Table 9). Deleting these samples, the ratio was 2.1:1 and was not significantly different among events ($\chi^2 = 2.37$, df = 3, $P > 0.05$).

DISCUSSION

While there were problems with representing age and size composition for the Mineral Lake Outlet Arctic grayling stock, I feel that the estimated adult compositions are representative of the spawning stock. As such, some comparisons can be made with data from other spawning stocks in the Tanana River Drainage. The Mineral Lake Outlet stock mature at a much smaller size than the stock in Caribou Creek, a spawning site and tributary of the Shaw Creek Drainage located approximately 281 km downstream. The LM_{50} of 232 mm FL for the Mineral Lake Outlet stock was significantly smaller than that found at Caribou Creek in 1987 (272 mm FL with a 95% CI of 276 to 382 mm; Ridder 1988). As a result of this small size at maturity, the adult relative stock density values are skewed to smaller size fish than those from pooled data from Caribou Creek and the Goodpaster River (Figure 5; Ridder 1988). The difference between size compositions of the three stocks was significantly different ($\chi^2 = 254.91$, df = 4, $P < 0.05$).

Whether the size composition of the adult stock in Mineral Lake Outlet is characteristic of a stock overexploited by anglers, as Tack (1972) suggested, or simply is a result of environmental or life strategy differences is open to conjecture. If the Mineral Lake Outlet spawning stock is overexploited, selection processes over the 28 years of the fishery would have favored slower growing individuals, resulting in a decline in average size and age. While the Mineral Lake Outlet adult stock size composition is smaller than for other stocks, comparisons of mean lengths at age among these same stocks do not show appreciable differences (Appendix Table 9). Unfortunately, small sample sizes in the Mineral Lake Outlet historical data base (Appendix Tables 6 to 8) make poor comparisons for detection of a decline in mean length at age. Assuming Arctic grayling home to spawning sites, continued sampling of Arctic grayling at Mineral Lake Outlet and sampling of spawning stocks in other waters of the Little Tok River or nearby drainages could help in determining if overexploitation has occurred.

Exploitation of the Mineral Lake Outlet stock after completion of their spawning activities could be considered minimal if angler tag return data is considered. Anglers returned two tags during the 1988 season. With 441 Arctic grayling tagged in 1988, this return represents a recapture rate of 0.5%. Recapture rates by anglers of Caribou Creek tags were 3.2% and 7.0% in 1987 and 1988, respectively. Tagging of prespawning Arctic grayling at the

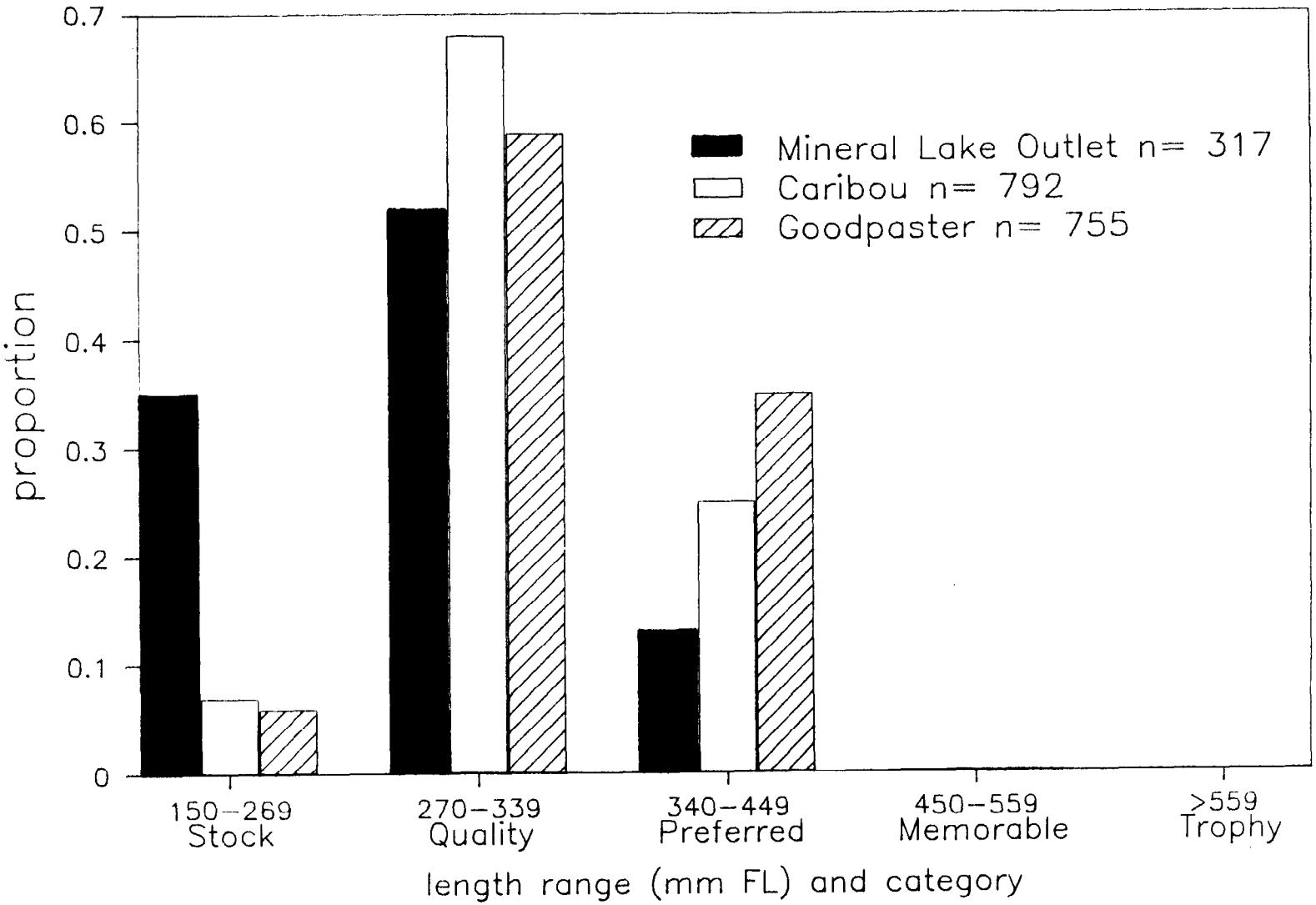

Figure 5. Relative Stock Densities for adult Arctic grayling captured in the spring at Mineral Lake Outlet (1988), Caribou Creek (1985 through 1987), and the Goodpaster River (1982, 1985 through 1987).

Table 9. Number of adult male and female Arctic grayling captured by site and sample event, Mineral Lake Outlet, 10 to 25 May 1988.

Site	Event	Number Sampled		Male : Female
		Male	Female	
1	1	18	6	3.0 : 1
1	2	74	35	2.2 : 1
1	3	52	31	1.7 : 1
1	4	20	6	4.5 : 1
1	5	0	0	---
2-5	6	34	12	2.9 : 1
6	7	4	8	0.5 : 1
6	8	0	9	0.0 : 1
6	9	0	2	0.0 : 1
Totals		209	109	1.9 : 1

mouth of Shaw Creek in 1987 and 1988 gave angler recapture rates of 4.3% and 2.0%, respectively (Ridder 1988).

An additional, although approximate, estimate of exploitation can be calculated from the percentage of Arctic grayling sampled that had injured mouths (assumed to be from hook and line releases or losses). Nine percent of the Arctic grayling greater than 199 mm FL sampled in Mineral Lake Outlet in 1988 had damaged mouths (Table 10). In 1985, hooking damage to Arctic grayling of the same size was 20% in Fielding Lake, 10% in Fielding Lake Outlet, 47% in the Tangle River, and 25% in Round Tangle Lake (Holmes et al. 1986). Arctic grayling with hooking injuries found from 1980 to 1984 ranged from 27% to 38% in the Delta Clearwater River and from 11% to 18% in Caribou Creek (Ridder 1985).

The abundance estimate of males at site 1 could be expanded by the estimated sex ratio to give total estimated abundance of 252 adults. However, the accuracy of the estimated sex ratio found in 1988 is questionable. Two hundred and nine males and 109 females were tagged and 77 males and 5 females were recaptured. The significant difference in these recapture rates ($\chi^2 = 21.95$, df = 1, $P < 0.05$) compared to their insignificant initial capture rate ($\chi^2 = 2.37$, df = 3, $P > 0.05$) suggests a gear bias based on differences in behavior of the sexes. Tack (1971) reported that females preferred pools when not actually spawning while males actively defended territories. Tack (1971) also found a sex ratio of 1.3:1 in a hook and line sample of 69 fish at the Outlet (Appendix Table 8).

The use of seines as a sampling tool in the Outlet has limitations that biased some of the estimates presented in the report. Seining was effective in only limited areas and failed to sample pools adequately. In areas where seining was effective, i.e. shallow runs and riffles, it could also be destructive to the substrate and to newly deposited eggs. Therefore, seining should be used with restraint. While a weir installation would be the preferred gear type, a suitable design to withstand all conditions would be costly to build and operate. A combination of gears including backpack electroshockers, hook and line, and seines could effectively sample all habitat types given favorable conditions.

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Table 10. Estimates of the proportional incidence of hooking injuries in 50 mm length classes for Arctic grayling sampled by seine in Mineral Lake Outlet, 10 to 25 May 1988.

Length Range(mm)	N[1]	Hooking damage		
		n[2]	p[3]	SE[4]
≤199	364	2	0.005	0.004
200-249	171	14	0.082	0.021
250-299	150	13	0.087	0.023
300-349	94	8	0.085	0.029
350-399	26	5	0.192	0.077
Totals:				
≥200	441	40	0.091	0.014
≥250	270	26	0.096	0.018
≥300	120	13	0.108	0.028

[1] N = total sample in length range.
[2] n = number with hooking damage in length range.
[3] p = proportion in length range with hooking damage.
[4] SE = standard error of the hooking damage proportion.

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APPENDIX

Appendix Table 1. Summary of sampling effort, catch, maturity, and sex compositions, and water temperatures by site at Mineral Lake Outlet, 10 to 25 May 1988.

Sample Event No.	Date	Site	Effort[1]	N[2]	n[3]	n_j[4]	n_a[5]	Sex		°C[8]
								n_m[6]	n_f[7]	
1	10 May	1	2	26	26	8	18	13	5	4°
1	11 May	1	1	9	9	3	6	5	1	4°
2	17 May	1	5	124	124	15	109	74	35	7°
3	18 May	1	4	198	196	68	130	96	34	7°
4	20 May	1	4	125	115	60	65	57	8	7°
5	25 May	1	1	156	38	156	0	---	---	11°
6	11 May	2	1	12	12	8	4	2	2	---
6	17 May	2	2	18	17	5	13	11	2	---
6	17 May	3	1	15	15	5	10	7	3	---
6	17 May	4	1	15	15	4	11	9	2	---
6	17 May	5	1	18	15	10	8	5	3	---
7	16 May	6	3	38	36	26	12	4	8	---
8	18 May	6	2	84	79	75	9	0	9	---
9	20 May	6	2	65	46	63	2	0	2	---
Totals				903	743	506	397	283	114	

[1] Effort = number of seine hauls.
[2] N = total catch includes 98 recaptures of fish tagged in previous events.
[3] n = catch with lengths greater than 149 mm FL.
[4] n_j = number of juveniles in N.
[5] n_a = number of adults in N.
[6] n_m = number of males in n_a.
[7] n_f = number of females in n_a.
[8] Water temperatures recorded between 1130 and 1300 hrs.

Appendix Table 2. Results of two-sample Kolmogorov-Smirnov tests on Arctic grayling greater than 149 mm FL between combinations of sampling events[1] at Mineral Lake Outlet, 1988.

Sampling Event[2]		Sample Size[3]			
First	Second	First	Second	D[4]	P[5]
1	2	35	124	0.1442	0.5610
1,2	3	159	196	0.2228	0.0002
1,2	4	159	115	0.3238	0.0000
1,2	5	159	38	0.8719	0.0000
2	3	124	196	0.3673	0.0000
2	6	124	74	0.2369	0.0088
2	8	124	79	0.7985	0.0000
3	4	196	115	0.1484	0.0685
3	6	196	74	0.1221	0.3617
3	8	196	79	0.5665	0.0000
3,4	2	311	124	0.2697	0.0000
3,4	5	311	38	0.6439	0.0000
3,4	7	311	36	0.2984	0.0053
3,4	8	311	79	0.5448	0.0000
3,4	9	311	46	0.6051	0.0000
3,4	6	311	74	0.0895	0.6776
3,4	7,8,9	311	161	0.4649	0.0000
7	8	36	79	0.3910	0.0006
8	9	79	46	0.3137	0.0048

[1] Date(s) and locations of sample events are presented in Appendix Table 1.
[2] Data collected from these sampling events used in Kolmogorov-Smirnov test.
[3] Number of fish lengths used in Kolmogorov-Smirnov test.
[4] D is the Kolmogorov-Smirnov test statistic.
[5] P = probability of a greater D. If less than $\alpha = 0.05$ reject null hypothesis of similar length distributions.

Appendix Table 3. Length frequencies, within 25 mm FL groups, of Arctic grayling in daily catches at site 1 (head pool) in Mineral Lake Outlet, 1988.

Range	Number of Fish				
	5/10-11	5/17	5/18	5/20	5/25
75 - 99	0	0	1	3	81
100 - 124	0	0	0	2	37
125 - 149	0	0	1	5	16
150 - 174	0	1	13	15	19
175 - 199	1	5	25	16	11
200 - 224	4	4	21	12	6
225 - 249	6	16	21	21	2
250 - 274	5	24	36	8	0
275 - 299	5	28	31	12	0
300 - 324	4	25	29	10	0
325 - 349	6	12	17	13	0
350 - 374	3	6	3	5	0
375 - 399	1	3	0	3	0
Totals	35	124	198	125	156

Appendix Table 4. Length frequencies, within 25 mm FL groups, of Arctic grayling in daily catches at site 6 (mouth) in Mineral Lake Outlet, 1988.

Range	Number of Fish			
	5/16	5/18	5/20	Total
75 - 99	0	0	0	0
100 - 124	0	1	4	5
125 - 149	2	4	15	21
150 - 174	2	12	20	34
175 - 199	10	33	17	60
200 - 224	5	22	4	31
225 - 249	9	10	4	23
250 - 274	5	1	1	7
275 - 299	4	1	0	5
300 - 324	1	0	0	1
325 - 349	0	0	0	0
350 - 374	0	0	0	0
375 - 399	0	0	0	0
Totals	38	84	65	187

Appendix Table 5. Length frequencies, within 25 mm FL groups, of Arctic grayling in daily catches at sites 2 through 5 in Mineral Lake Outlet, 11 and 17 May 1988.

Range	Number of Fish					
	Site 2	Site 2	Site 3	Site 4	Site 5	Total
75 - 99	0	0	0	0	0	0
100 - 124	1	0	0	0	0	1
125 - 149	0	0	0	0	3	3
150 - 174	1	0	4	0	1	6
175 - 199	2	1	0	1	2	6
200 - 224	1	3	0	2	2	8
225 - 249	2	3	3	1	3	12
250 - 274	2	2	0	6	2	12
275 - 299	2	1	2	2	1	8
300 - 324	0	1	2	1	3	7
325 - 349	1	0	2	2	1	6
350 - 374	6	1	2	0	0	9
375 - 399	0	0	0	0	0	0
Totals	18	12	15	15	18	78

Appendix Table 6. Summary of age composition estimates and standard errors for Arctic grayling sampled in Mineral Lake Outlet, 1970 - 1988[1].

	1970			1974			1979			1988		
Age Class	n[2]	p[3]	SE[4]	n	p	SE	n	p	SE	n	p	SE
1	0	---	---	0	---	---	0	---	---	102	0.137	0.013
2	2	0.029	0.020	0	---	---	0	---	---	79	0.106	0.011
3	11	0.159	0.044	0	---	---	0	---	---	182	0.326	0.020
4	32	0.464	0.060	1	0.029	0.029	7	0.412	0.119	139	0.249	0.018
5	11	0.159	0.044	4	0.118	0.055	3	0.176	0.092	96	0.172	0.016
6	5	0.072	0.031	11	0.324	0.080	3	0.176	0.092	60	0.107	0.013
7	6	0.087	0.034	11	0.324	0.080	3	0.176	0.092	39	0.070	0.011
8	1	0.014	0.014	4	0.118	0.055	1	0.059	0.057	29	0.052	0.009
9	1	0.014	0.014	2	0.058	0.	0	---	---	10	0.018	0.006
10	0	---	---	0	---	---	0	---	---	4	0.007	0.004
11	0	---	---	0	---	---	0	---	---	1	0.001	0.001
12	0	---	---	1	0.029	0.029	0	---	---	1	0.001	0.001
Total	69	1.000		34	1.000		17	1.000		742	1.000	

[1] Data sources: 1970 - Tack (1971); 1974 and 1979 - Delta Field Office files.
[2] n = sample size.
[3] p = proportion.
[4] SE = standard error of the proportion.

Appendix Table 7. Summary of Relative Stock Density (RSD) indices for Arctic grayling (≥ 150 mm FL) sampled from Mineral Lake Outlet, 1970 - 1979[1].

	RSD Category[2]				
	Stock	Quality	Preferred	Memorable	Trophy
15 May 1970					
Number sampled	4	7	1	0	0
RSD	0.333	0.583	0.083	---	---
Standard Error	0.136	0.142	0.080	---	---
20 May 1973					
Number sampled	1	6	1	0	0
RSD	0.125	0.750	0.125	---	---
Standard Error	0.117	0.153	0.117	---	---
21 May 1974					
Number sampled	4	31	7	0	0
RSD	0.095	0.738	0.167	---	---
Standard Error	0.045	0.068	0.058	---	---
19 May 1976					
Number sampled	12	17	2	0	0
RSD	0.387	0.548	0.065	---	---
Standard Error	0.087	0.089	0.044	---	---
22 May 1979					
Number sampled	14	3	0	0	0
RSD	0.824	0.176	---	---	---
Standard Error	0.092	0.092	---	---	---

[1] Data from field office files, ADFG, Delta Junction. All sampling at head of outlet. Gear type: 1970, unknown; 1973, gill net; 1974 -1979, hook and line.

[2] Minimum lengths (FL) for RSD categories are (Gablehouse 1984):

Stock - 150 mm
Quality - 270 mm
Preferred - 340 mm
Memorable - 450 mm
Trophy - 560 mm

Appendix Table 8. Summary of mean length at age data[1] for Arctic grayling sampled at Mineral Lake Outlet, 1970 - 1988.

	1970			1974			1979			1988		
Age Class	n[2]	mean	SD[3]	n	mean	SD	n	mean	SD	n	mean	SD
1	0	---	---	0	---	---	0	---	---	102	89	10
2	2	162	ND[4]	0	---	---	0	---	---	79	147	21
3	11	192	ND	0	---	---	0	---	---	182	181	19
4	32	226	ND	1	280	---	7	214	7	139	223	23
5	11	269	ND	4	287	27	3	229	10	96	265	22
6	5	309	ND	11	308	17	3	244	15	60	284	24
7	6	341	ND	11	308	24	3	267	40	39	311	28
8	1	363	---	4	326	22	1	306	---	29	330	20
9	1	371	---	2	348	8	0	---	---	10	360	22
10	0	---	---	0	---	---	0	---	---	4	353	16
11	0	---	---	0	---	---	0	---	---	1	384	---
12	0	---	---	1	410	---	0	---	---	1	378	---
Total	69	ND	---	34	312	30	17	287	47	742	214	81

[1] Data sources: 1970 - Tack (1970); 1974 and 1979 - Delta Field Office files.
[2] n = sample size.
[3] SD = sample standard deviation.
[4] ND = no data in citation.

Appendix Table 9. Estimated mean fork length at age for Arctic grayling sampled during the spring from Mineral Lake Outlet (1988), Caribou Creek (1986 - 1987), and the Goodpaster River (1982, 1985 - 1987)[1].

	Mineral Lake				Caribou Creek				Goodpaster River			
Age Class	n[2]	mean	SD[3]	SE	n	mean	SD	SE	n	mean	SD	SE
1	102	89	10	1	20	96	10	2	2	96	11	11
2	79	147	21	2	51	141	15	2	13	135	22	6
3	182	181	19	1	177	203	21	2	104	182	20	2
4	139	223	23	2	276	234	21	1	93	221	14	1
5	96	265	22	2	195	269	21	2	199	252	20	1
6	60	284	24	3	138	299	21	2	190	281	24	2
7	39	311	28	4	184	324	22	2	162	304	28	2
8	29	330	20	4	92	349	22	2	90	326	26	3
9	10	360	22	7	32	361	21	4	57	352	24	3
10	4	353	16	8	15	372	27	7	22	369	27	6
11	1	384	---	---	3	398	42	30	10	386	19	6
12	1	378	---	---	3	400	8	6	3	414	26	18
13	0	---	---	---	0	---	---	---	2	416	14	14
Total	742	214	81	3	1,186	256	65	2	947	272	61	2

[1] Data sources: Caribou Creek, Ridder (in press); and, Goodpaster River, Ridder (in press).
[2] n = sample size.
[3] SD = sample standard deviation.